unit

20 A

Energy and Matter Exchange in the Biosphere

About 50 years ago, the first photographs taken from space allowed us to see our planet as a whole. Traditional Western thought saw Earth's natural resources as infinite and viewed nature as a force to be dominated for our benefit. Such views are now linked to many environmental problems. Satellite images often reveal scars on our planet from human activities, such as forests that are burned away to create agricultural land or the silting of waterways, such in the Mississippi River Delta shown in the photograph. However, we have now learned that the best way to correct and prevent these problems is to ensure our activities are carried out in ways that help to maintain the natural balance of the biosphere. When we view humanity as an integral part of the biosphere, connected to all living things, we begin to consider not only the ways that science and technology can change natural ecosystems, but also how those changes will impact us.

As you progress through the unit, think about these focusing questions:

- How are carbon, oxygen, nitrogen, and phosphorus cycled in the biosphere?
- How is the flow of energy balanced in the biosphere?
- How have human activities and technological advances affected the balance of energy and matter in the biosphere?

UNIT 20 A PERFORMANCE TASK

Environmental Effects of Human Communities

In this Performance Task, you will choose one of three tasks that will demonstrate your understanding of how ecosystems are sustained, and the effects of human activities. The first task considers golf. In many areas, new courses are appearing in what was farmland or forest. How might you create a golf course with minimum impact on local ecosystems? The second task considers community water quality. We use water for many purposes, such as for drinking, building, making chemicals, and transporting goods. How could you monitor the impact of human activities on a local body of water? Finally, you might create an educational board game that will help players learn about ecosystems and how they can be sustained.

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GENERAL OUTCOMES

In this unit, you will

- explain the constant flow of energy through the biosphere and ecosystems
- explain the cycling of matter through the biosphere
- explain the balance of matter and energy exchange in the biosphere as an open system, and how this maintains equilibrium

Unit 20 A
Energy and Matter Exchange in the Biosphere

ARE YOU READY?

These questions will help you find out what you already know, and what you need to review, before you continue with this unit.

Prerequisites

Concepts

- biotic and abiotic factors
- producers, consumers, and, decomposers
- food chains and food webs
- the water cycle
- open and closed systems
- thermal energy transfer in the biosphere

Skills

- select and use appropriate vocabulary to communicate scientific ideas
- use graphs to compile, organize, and interpret data

You can review prerequisite concepts and skills on the Nelson Web site and in the Appendices.

A Unit Pre-Test is also available online.

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Knowledge

1. Use **Figure 1** to identify the following:
   (a) two biotic and two abiotic factors
   (b) a producer, a consumer, and a decomposer
   (c) three different food chains of at least three organisms each

Figure 1
An ecosystem

2. Describe the role of producers in an ecosystem.
3. Could an ecosystem continue if all the decomposers were removed? Why or why not?
4. Describe how water is cycled within ecosystems.
5. Identify two ways that thermal energy (heat) is transferred from one region of Earth to another.
6. Distinguish between an open system and a closed system.

Skills

7. Using a diagram, describe the greenhouse effect.
8. In your notebook, sketch **Figure 2** or write labels to represent the organisms. Draw arrows to complete a food web.

Figure 2

STS Connections

9. Why should we be concerned with air and water pollution that is happening on the side of Earth opposite to where we live?
10. Attitudes toward the environment have changed over time. Using specific examples, describe evidence that Canadians' attitudes have changed over time. Is there still a need for changes in attitude? Explain your answer.
11. Different cultures often look differently at the relationships between living organisms and their ecosystems.
    (a) Using the wolf as an example, explain the different worldviews of Aboriginal people and early European settlers.
    (b) Is there any evidence that the view of the early European settlers is no longer held by Canadians?

chapter

1 The Biosphere as a Closed System

In this chapter

In the traditional knowledge of Canada's Aboriginal peoples, nature is full of interconnections and complexities. Spiritual stories describe how animals are connected to living things such as plants and other animals, non-living things such as air or water, and natural events such as storms. For example, the Sandy Lake Cree tell of the thunderbird Binay-sih, who protects other animals from the sea serpent, Genay-big. Binay-sih's anger is expressed through black clouds, thunder, and lightning. Humans are just one of the many connected elements.

In contrast, a traditional Western view is that nature is a source of raw materials or products to be exploited for human needs. This narrow viewpoint has sometimes led us to damage the environment and, in turn, damage ourselves. For example, the recent oil spill at Wabamun Lake can be seen as a conflict between our need for oil and the needs of the organisms in that environment.

Today, scientists from various cultures recognize that they must look at the world differently to meet our need and sustain our planet. Although Western scientific thought and traditional Aboriginal culture have different starting points, both offer important insights into how ecosystems work.

STARTING Points

Answer these questions as best you can with your current knowledge. Then, using the concepts and skills you have learned, you will revise your answers at the end of the chapter.

1. Explain this statement: "An ecosystem is constantly changing, yet it remains the same."
2. Describe a typical food web in your region. Be sure to include producers, consumers, and decomposers.
3. Do you think that Earth's ecosystems can withstand the current negative impacts of human activity? What evidence supports your opinion?
4. A commonly held stereotype is that traditional Aboriginal lifestyles had/have no negative impact on the environment. Recently, writers and researchers have acknowledged that buffalo jumps (which killed more buffalo than were needed) and the burning of forests for agricultural land are inconsistent with this perception. Explain why even positive stereotypes can be dangerous.

Career Connection:
Photographer (Scientific)

Figure 1
On August 3rd, 2005, a train derailed at Lake Wabamun, Alberta. More than 1 million litres of oil were spilled, causing severe environmental damage.

Exploration — Earth under a Microscope

Purpose
To investige how living things interact in a closed system on a small and simple scale, by observing microscopic organisms

Materials: tap water; medicine dropper; microscope slides and coverslips; microscope; cultures of yeast, *Paramecium*, and *Didinium*

Use gloves while making and observing the slides. Dispose of slides and gloves as directed by your teacher. Wash your hands before leaving the lab.

- Using a medicine dropper, prepare separate wet mounts from each of the three cultures. Examine each slide under a light microscope.

(a) For each slide, how many different kinds of living things do you see?
(b) Sketch and describe the organism(s) on each slide.
(c) Describe the behaviour of the organism(s) on each slide.

- Combine the living organisms to observe how they interact. Prepare the following wet mounts:

  1 drop *Paramecium* culture + 1 drop yeast culture
  1 drop *Paramecium* culture + 1 drop *Didinium* culture

(d) Describe the interactions between the organisms.
(e) How would an ecosystem that contained all three organisms be different from one that contained only *Paramecium*?

EXTENSION

Using the Light Microscope
Listen to a review of the proper use of a light microscope.

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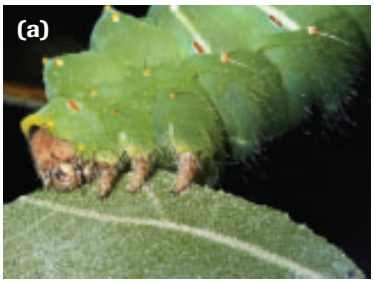
1.1 Equilibrium in the Biosphere



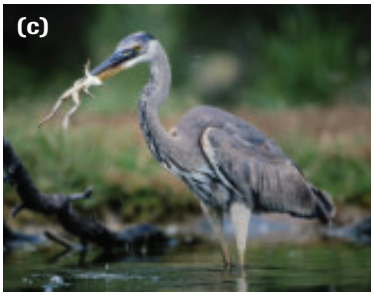


Figure 1
Interactions among biotic components: **(a)** a plant and an insect, **(b)** an insect and an amphibian, **(c)** an amphibian and a bird

"We do not inherit the Earth from our grandparents; we borrow it from our grandchildren."—Chief Seattle

Imagine how the Apollo astronauts felt when they first set foot on the Moon and saw the spectacle of the living Earth rising above the lifeless lunar rock. From that viewpoint, one might think of our planet as a spaceship. Travelling around the Sun in a slightly elliptical orbit, Earth carries with it the only forms of life confirmed in the universe. As you learned in your previous studies, Earth is a closed system, which is any system in which *matter* is not exchanged with its surroundings. A closed system exchanges *energy* with its surroundings, however. Life is totally dependent on incoming solar energy and the matter available on Earth.

When we see the whole planet from a distance, we can see that everything on Earth is connected. There are no real boundaries. The atmosphere that envelops Earth is continuous and free to flow. The oceans are continuous, even though we have given the oceans separate names.

This distant view of Earth shows us the big picture. It does not allow us to see the countless continuous interactions among living and non-living components that take place in this system. We do not see the insect feeding on the leaves of a tree, or the frog feeding on the insect, or the bird eating the frog (**Figure 1**), or any other details of a complex web of activity that keeps the system running. Neither can we see the impacts of human activity—the treeless hills; the smog hanging over cities, and the polluted rivers, lakes, and oceans—or the efforts of humans to prevent species extinction or to preserve the natural environment.

J.E. Lovelock, a British scientist, compares Earth to a living body. The metaphor is referred to as the *Gaia* (pronounced "gay-ah") *hypothesis*, named after the Greek goddess of Earth. Although a controversial idea in the scientific community, it serves to emphasize that all living things interact with each other and with the non-living components of our planet. In much the same way that the brain requires oxygen and nutrients from the circulatory system to function properly, each component of Earth's environment must be in a state of balance or equilibrium with every other component. What affects one part affects all parts. The expression **dynamic equilibrium** is used to describe any system in which changes are continuously occurring but whose components have the ability to adjust to these changes without disturbing the entire system.

dynamic equilibrium describes any system with constant change in which the components can adjust to the changes without disturbing the entire system

Today's ecologists have evidence to suggest that Earth is facing a crisis in which its dynamic equilibrium is being upset. However, scientists have not reached a consensus about the magnitude of the predicament or what can be done. The problems appear to result from the activities of a single dominant species: humans. We humans can also be a positive force in preserving the dynamic equilibrium of Earth. We have the ability to understand natural processes and act on this knowledge. As a member of Earth's community, you can become a knowledgeable decision maker by studying some of the well-established principles of ecology. The decisions you make will, in part, determine the future direction of life on this small and fragile planet.

The Biosphere

Earth has three basic structural zones: the lithosphere (land), the hydrosphere (water), and the atmosphere (air). Living organisms are found in all three zones. Together, these three zones make up the **biosphere**, the narrow zone around Earth that harbours life.

biosphere the narrow zone around Earth that harbours life

The limits of the biosphere extend from the ocean depths all the way to the atmosphere. Most terrestrial animals are confined to a narrow band where the atmosphere meets the surface of the earth. The regions that are not within the biosphere, such as the upper atmosphere and Earth's core, are also important because they affect living organisms.

Life forms are referred to as the **biotic**, or living, components of the biosphere. Chemical and geological factors, such as rocks and minerals, and physical factors, such as temperature and weather, are referred to as the **abiotic**, or non-living, components. It is the interactions within and between the biotic and abiotic components that the ecologist endeavours to understand and explain.

When biologists investigate how a complex organism functions, they must study its various levels of organization. Moving from the simple to the more complex, these levels are individual cells; then tissues; organs and organ systems; and finally the integrated, functioning body. Ecologists investigating the biosphere proceed in a similar manner. By examining its individual parts, ecologists are able to bring together the various data and provide a picture of how the biosphere operates as an integrated unit.

Ecological studies begin at the organism level. Investigations are designed to determine how the individual interacts with its biotic and abiotic environment. However, an organism does not live in isolation. It tends to group with others of the same species into **populations**. A population influences, and is influenced by, its immediate environment. When more than one population lives in an area, a **community** of organisms is established. An **ecosystem**, the functional unit of the biosphere, has both biotic and abiotic components. The physical and chemical environment, as well as the community of organisms, interact with each other in an ecosystem.

biotic components the biological or living components of the biosphere

abiotic components the non-living components of the biosphere. They include chemical and physical factors.

population a group of individuals of the same species occupying a given area at a certain time

community the populations of all species that occupy a habitat

ecosystem a community and its physical and chemical environment

biodiversity the number of species in an ecosystem

food chain a sequence linking organisms that feed on each other, starting with a food source and continuing in order with each consumer

producer an autotroph; an organism that makes its own food

consumer a heterotroph; an organism that must eat producers or other consumers to survive

Biodiversity

The number of species in an ecosystem is described as the biological diversity or **biodiversity** of the ecosystem. Because every organism in an ecosystem is connected to all the other organisms, the reduction in biodiversity caused by the extinction of a single species can cause a domino effect. The loss of one part from an ecosystem, like the removal of a moving part from a car, can cause the collapse of an entire food chain. A **food chain** is a step-by-step sequence linking organisms that feed on each other, starting with a food source such as plants (**producers**), and continuing with animals and other living things that feed on the plants and on each other (**consumers**). When a species acts as a predator, it keeps the population of its prey in check; when it acts as prey, it provides an important food source.

For example, the overhunting of sea otters along the Pacific coasts of Asia and North America removed the main predator of the sea urchin. Predictably, the number of sea urchins grew rapidly. Sea urchins eat kelp, a form of seaweed. As the number of sea urchins grew, the amount of kelp declined, and so did the fish that relied on the kelp-bed ecosystem for habitat and food. Sea otters very nearly became extinct as a result of hunting pressure. From the point of view of humans, killing sea otters for their fur resulted in the decline of a valuable fishery. Where the sea otter has been reintroduced, sea urchin populations have fallen, kelp beds are being re-established, and the number of fish is increasing.

The story of the whooping crane (**Figure 2**) is another example of an attempt to restore a natural balance. In spring, whooping cranes fly north to live in the marshes and swamps of the prairies and the Canadian north, where they eat crayfish, fish, small mammals, insects, roots, and berries. Efforts by conservationists have helped increase the population from a low of 14 individuals in 1940 to 213 in 2004. Chemical pesticides were the original human threat to the crane, but it was already struggling. Cranes fly a

Figure 2
The efforts of wildlife biologists are preventing the whooping crane from becoming extinct. Some young birds are hand-raised but, to prevent the chicks from associating humans with safety, the caregivers disguise themselves as adult cranes.

EXTENSION

Why is Biodiversity a Good Thing?

Learn more about how species' survival is connected to the biodiversity of a region.

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long way during their migration, and are vulnerable to hunting and accidents along the way. In addition, the whooping crane reproduces very slowly. Each year females produce two eggs; however, only one will mature. The first fledgling to emerge from its egg kills its brother or sister. This ensures there will be enough food for the survivor, but it also reduces the rate at which the population can increase.

We do not fully understand all the relationships between species in many ecosystems, so we cannot predict reliably what will happen to an ecosystem if its biodiversity is reduced, even by one species.

Figure 3
Dr. David Suzuki

WEB Activity

Canadian Achievers—Dr. David Suzuki

Dr. David Suzuki (**Figure 3**) is perhaps Canada's most recognizable living scientist. Through his many books and his popular CBC television show "The Nature of Things," Suzuki has taken science out of the laboratory and into people's day-to-day lives. One of Dr. Suzuki's main interests is environmental issues. Explore David Suzuki's contributions to environmental studies further, and find out his opinions on Canada's ecosystems. Think about the following questions:

Which ecosystems in Canada are most at risk?

How does the level of risk relate to biodiversity?

What role does human activity play in loss of biodiversity?

What can you do to reverse this trend?

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SUMMARY Equilibrium in the Biosphere

- Earth supports the only confirmed life forms in existence. Living organisms are found in a limited region of Earth known as the biosphere.
- The expression *dynamic equilibrium* is used to describe any system in which changes are continuously occurring but the components have the ability to adjust to these changes without disturbing the entire system.
- The number of species in an ecosystem is described as the biological diversity or biodiversity of the ecosystem. Since organisms interact with each other in potentially important and unique ways, the reduction in biodiversity caused by the extinction of a single species can cause a "domino effect."

Section 1.1 Questions

1. How can the metaphor of a spaceship be used to describe Earth?
2. What is a closed system?
3. What are the abiotic and biotic components of the biosphere?
4. In what way does a community differ from an ecosystem?
5. Name the levels of organization in the biosphere.
6. Using the organisms in **Figure 1**, on page 8, as an example, explain how ecosystems are in a state of dynamic equilibrium.
7. (a) In your own words define the term *biodiversity.*
   (b) Explain why diversity is important for ecosystems.
   (c) Give two examples of ecosystems that have high biodiversity, and two that have low biodiversity. Explain your classification.
8. Canadian wildlife biologists have been attempting to preserve the whooping crane. Are they succeeding? In a short essay, evaluate the success of their program.

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Equilibrium Unbalanced 1.2

The first bald eagle born and raised on the shores of Lake Erie in nearly 30 years took flight in 1983. Wildlife officers had moved the parent birds to Long Point peninsula in an attempt to re-introduce the birds to the natural ecosystem in the lower Great Lakes.

During the 1700s and 1800s the bald eagle was common along the northern shores of Lake Erie. By the early 1900s, biologists began to see a decline in their numbers. Early settlers and farmers regarded the birds as a threat to livestock and often killed them. A second, and even more deadly, threat followed. Toxic chemical waste, produced by the many industrial plants that bordered the Great Lakes, entered the eagles' food chain. The high levels of toxins caused eggshells of the bald eagle and some other birds, such as the double-crested cormorant and the herring gull, to become unusually thin. Eggs broke more easily, and many eagles were born with abnormalities. Their birth rate declined significantly.

Eagles depend directly or indirectly on all of the other members of their food chain (**Figure 1**). The health of top-level consumers like eagles indicates whether toxins are entering an ecosystem. When the dynamic equilibrium of an ecosystem becomes unbalanced for any reason, the health or numbers of organisms in that ecosystem are affected. If the changes are large enough, some organisms may even become extinct. Eagles are one of many species that are providing evidence that changes in ecosystems are affecting the natural equilibrium in a negative way. In Canada, more than 450 species of plants and animals are at various degrees of risk, and 12 species have become extinct.

At-risk species are classified depending on the degree of risk. An *endangered* species is one that is close to extinction in all parts of the country or in a significantly large location. An *extirpated* species is one that no longer exists in one part of the country, but can be found in others. A *threatened* species is any species that is likely to become endangered if factors that make it vulnerable are not reversed. The term *special concern* refers to any species that is at risk because of low or declining numbers at the fringe of its range or in some restricted area. **Figure 2** gives some examples of at-risk species across Canada.

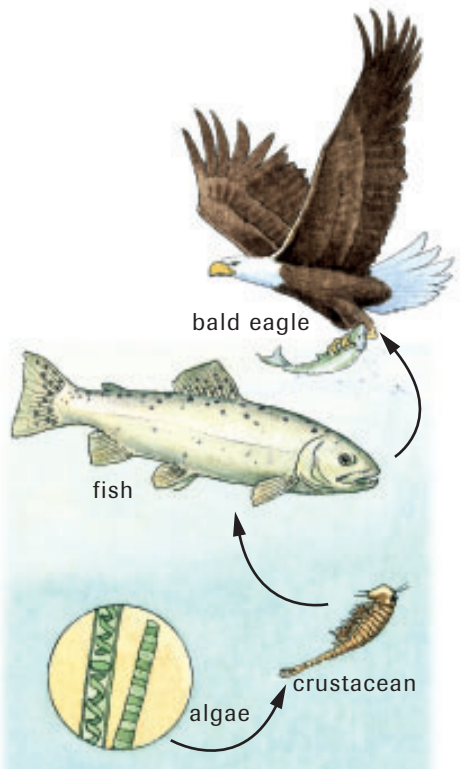

Figure 1
The bald eagle has been reintroduced to the shores of Lake Erie, in an attempt to re-establish a natural ecosystem.

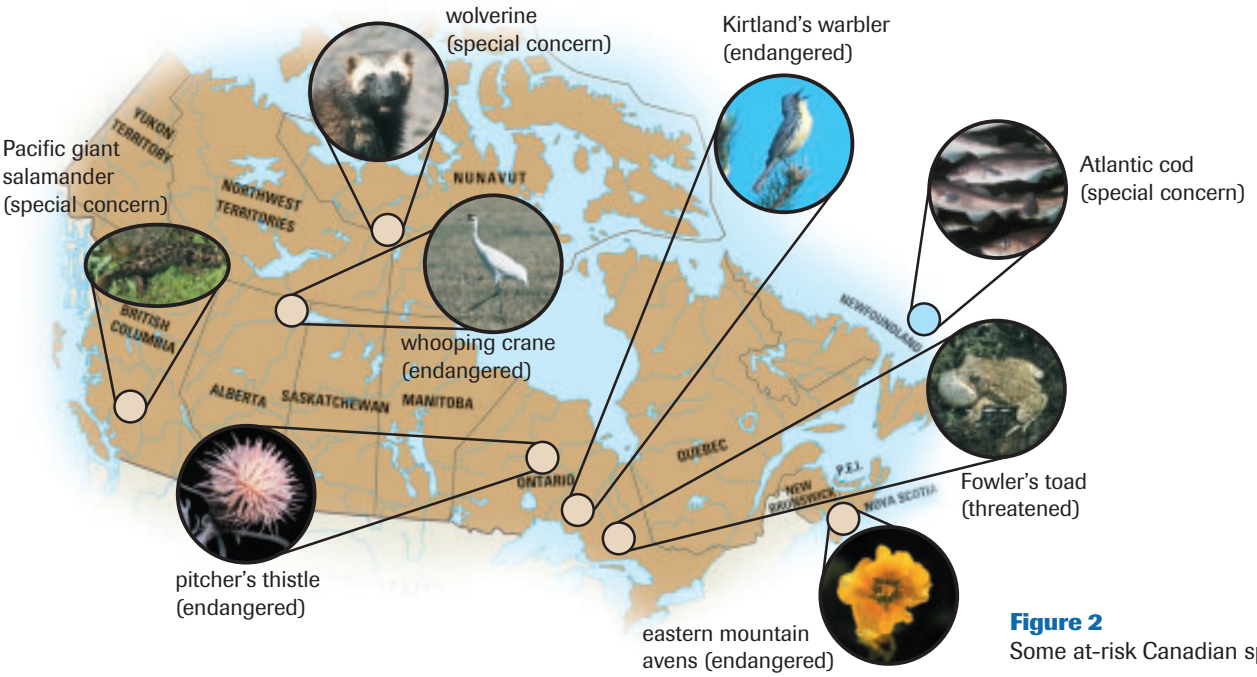

Figure 2
Some at-risk Canadian species

WEB Activity

Web Quest—Creating a Database of At-Risk Species

Create an electronic database of endangered species in Canada. First, decide on the categories you will use to describe the information (e.g., type of species, level of risk, and habitat). Then, create a table to define the categories that you want to use to record your data. Include different types of organisms in your database. After you have finished your database, test it by searching according to different categories. Show another group how your database works. Import the data recorded by the other group to make a larger database.

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The Disappearance of Frogs

indicator species a species sensitive to small changes in environmental conditions

Some species are particularly sensitive to changes in an ecosystem. These **indicator species** can provide an early warning that the balance in an ecosystem is being negatively affected. Some amphibians may be especially important indicator species. Why might this group of animals play such an important role?

The word *amphibian* is a clue. The word comes from two Greek words, *amphi* ("on both sides") and *bios* ("life"). Amphibians literally have two lives (**Figure 3**). Frogs begin as eggs and grow to tadpoles in ponds, and then enter their second life as adults in forest and grassland areas. This means they are exposed to hazards in both ecosystems, instead of only one. Any decline in the health of either of the two ecosystems in which they live will have an impact on frogs.

Not only do frogs occupy two different ecosystems, they are also parts of two very different food chains. Adult frogs eat mostly insects and a few small fish. In turn, large fish, predatory birds, reptiles, and small mammals eat frogs. This makes the adult frog a member of a food chain (**Figure 4**, next page) that includes producers (plants), **herbivores** (animals that eat plants), and **carnivores** (animals, like the frog, that feed on other animals). Animals that eat both plants and animals, such as humans, raccoons, and bears, are called **omnivores**.

herbivore an animal that eats only plants

carnivore an animal that feeds only on other animals

omnivore an animal that eats both plants and other animals

If frogs became extinct, insect populations would soar. This has already happened in Bangladesh, where frog populations have been decimated to supply restaurants with delicacies. The result is a rise in the number of mosquitoes, and a dramatic rise in cases of malaria among humans. Malaria is a disease that is transmitted by mosquitoes, which are eaten by frogs. The increase in malaria can be traced back to the disappearance of frogs from the local ecosystems.

(a)

(b)

Figure 3
The northern leopard frog, native to Alberta, is one of the threatened amphibian species. **(a)** Leopard frogs lay their eggs in ponds, and tadpoles develop. **(b)** Adult leopard frogs live in fields and around ponds.

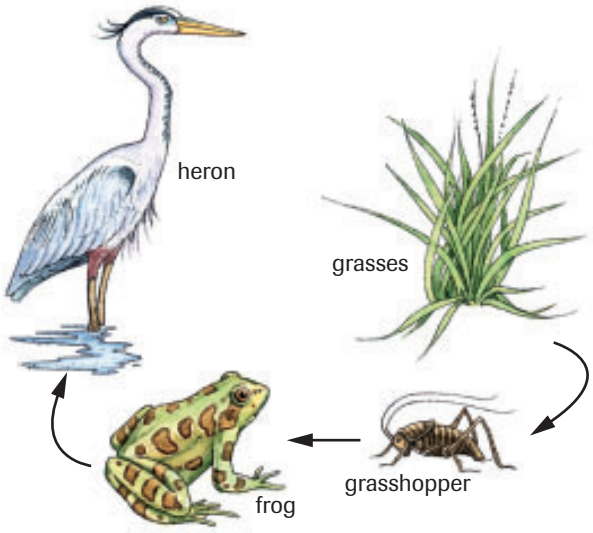

Figure 4
The adult frog is part of a food chain that includes producers (plants) that make food and consumers (animals) that feed either directly or indirectly on the plants.

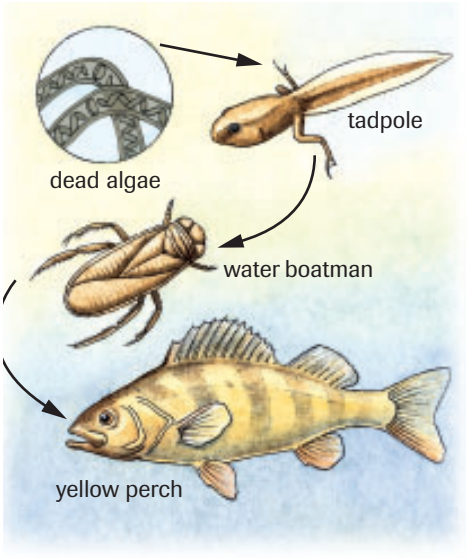

Figure 5
Waste is recycled within a detritus food chain. Organisms in the chain include fungi, bacteria, insects and other invertebrates, and, in ponds, tadpoles.

Tadpoles eat large amounts of algae (small plantlike organisms), both living and dead. The tadpole is a herbivore, not a carnivore, and is part of a different food chain than that of its parents (**Figure 5**). In this food chain, there are two food sources—producers (the algae) and **detritus** (waste from plants and animals, including their dead remains). Detritus food chains are critical in the recycling of matter in ecosystems. They include **decomposers**, organisms that break down detritus to get nutrients for their own use, but in the process also release nutrients to the soil and water. Plants and algae use those nutrients to grow.

detritus waste from plants and animals, including their dead remains

decomposer an organism that feeds on detritus

Why Are Frogs Disappearing?

Amphibians have been around for more than 400 million years. They survived the catastrophe that killed all the dinosaurs 65 million years ago. They have adapted to ice ages and extended periods of global warming, withstanding drought, flood, and winter ice. They can be found in most ecosystems that include water. Amphibians live on the peaks of the Canadian Rockies, in the city parks of Winnipeg, and in the swamps of Newfoundland. They have even done well dealing with the growth of the human population, at least until recently. Biologists have become aware of the gradual disappearance of amphibians such as frogs, toads, and salamanders. These animals seem to be dying at unprecedented rates. About 30 % of North America's frogs and toads are in trouble. The worldwide disappearance of frogs is puzzling scientists around the globe. In some areas, they have identified a few probable causes.

Loss of Habitat

In Canada, frogs in more heavily populated areas seem to be in great danger. The loss of **habitat**, places where a species can live, is usually thought to be the main cause. Frogs need wetlands, ponds, or lakes with clean water so they can breed and lay their eggs. As adults, they need a place where they can catch insects, such as a forest or a field. They also need a safe path between the two. The growth of cities, and human activities such as

habitat a place or type of environment with conditions suitable for the survival of an organism or population of organisms

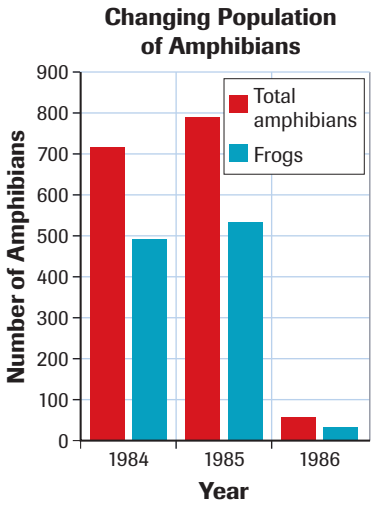

Figure 6
In the first year of the study, researchers counted 716 amphibians, 493 of which were frogs. After the trees were cut in 1986, they found very few.

CAREER CONNECTION

Photographer (Scientific)
Scientific photographers use high-tech equipment to take specialized photographs, such as photomicrography and time-lapse photography. Forensic photography is one specialization that is used to provide evidence for criminal investigations. If using computers, high-tech cameras, and media equipment interests you, research more about this career.

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ultraviolet radiation electromagnetic radiation from the Sun that can cause burning of the skin (sunburn) and cellular mutations

ozone O_3, an inorganic molecule. A layer of ozone found in the stratosphere helps to screen out ultraviolet radiation.

farming and industry, take away all of these things. Humans drain wetlands, cut down trees, build on fields, and build roads between ponds and woods.

A highway separating a woodlot from a pond or lake can claim the lives of many frogs as they move between their feeding and breeding areas. Cutting down some of the trees that surround a lake creates problems for amphibians by exposing them to increased UV radiation and predation. **Figure 6** shows data from one study, carried out from 1984 to 1986, in which scientists studied an area where a swamp and a forest were separated by a road. When trees bordering the road were cut in 1986, researchers noticed a huge decline in the number of frogs and other amphibians.

Air and Water Quality

A second cause for the decline in frog numbers is pollution. This is because frog skin is thin and is not protected by feathers, fur, or scales. Frogs have lungs, but they also breathe through their skin, which must be thin to allow oxygen through. Pollutants can also pass through their thin, moist skin. The pollutants in acid rain are known to harm frogs.

Acidity also affects frogs' ability to reproduce. Researchers have noted that if the water in which eggs are laid is even slightly acidic, it reduces the mobility of frog sperm cells. This makes it less likely that eggs will be fertilized. Even if mating is successful, acid affects the frog's development. Embryos, if they develop at all, grow slowly in acidic water. Some ponds may dry up before tadpoles can become adult frogs, and the tadpoles die. Acidic water can cause other problems, such as deformed limbs. Tadpoles with such limbs do not survive for very long.

Climate Change

Climate change may be another factor in the disappearance of frogs. Evidence of global warming is growing. Increasing global temperatures have been linked to the increased use of fossil fuels such as coal, oil, and gasoline. Climate change can cause important changes in local ecosystems. For example, if the climate becomes drier, frog populations will decline. No frog can stay in direct sunlight too long or completely separate itself from fresh water.

Ultraviolet Radiation

The thin skin of the frog is also susceptible to **ultraviolet** (UV) **radiation**. This invisible radiation from the Sun causes sunburns, but it has also been linked with more serious cell damage. The amount of UV radiation reaching Earth's surface is increasing because of damage to the protective **ozone** layer surrounding our planet. A thin layer of ozone (O_3) blocks harmful solar radiation. The layer is getting thinner. Atmospheric scientists believe that chlorofluorocarbons (CFCs), which were widely used in spray cans and refrigerators, are at least partly responsible for the thinning.

Frog species that live at higher altitudes, where the UV radiation is greater, seem to be most vulnerable to changes in the ozone layer. Many of these species have adaptations to protect them from high levels of UV radiation. For example, some species lay black eggs and have a black covering lining their internal organs. However, biologists are concerned that these adaptations may not be enough if change in the ozone layer continues to increase UV radiation levels in this habitat.

The frog is not the only animal whose skin is exposed to UV radiation. Humans also have a delicate skin and are affected by the increase in UV rays. Areas of thinning ozone have been identified above Antarctica and the Canadian Arctic. The concurrent increase in skin cancers and eye problems associated with ultraviolet radiation are raising much concern among ecologists and the general public. The fact that the rate of human skin cancer is rising all over the world underscores the importance of studying the frog as a "bioindicator" of the health of the planet.

EXPLORE an issue

Issue Checklist

○ Issue	○ Design	● Analysis
● Resolution	● Evidence	● Evaluation

What Is the Value of Wolves?

Few animals stir as many emotions as the wolf (**Figure 7**). Some Aboriginal peoples saw the wolf as a traveller, a guide, and a teacher, capable of appearing and disappearing at will. People saw many similarities to humans in the way wolves co-operate.

In contrast, the wolf of European stories chased three little pigs, disguised itself in the fleece of a lamb, and ate the grandmother of Little Red Riding Hood. Unlike the Native peoples of the plains, Europeans saw the wolf as a sharp-toothed villain that preyed on livestock and people.

The Decline of the Wolf

When European settlers reached central North America and found plains covered in bison, they were not willing to compete with the wolf for valuable hides. Thousands of wolves died after they ate poisoned bison carcasses that had been laid out as bait.

After the bison hunters left, having killed most of the bison, there was a break of a few years before ranchers began to kill wolves in the 1880s and 1890s. In both the United States and Canada, anyone bringing a wolf skin to a local government office was paid. In Montana alone, more than 80 000 wolves were destroyed between 1883 and 1918.

However, the effects of removing the wolves were dramatic. It was followed by an increase in the population of the next dominant predator, the coyote. The coyote, a close relative of the wolf, is smaller and rarely forms packs. Bison and elk are much too large for single coyotes to hunt. The coyote eats mostly small mammals, such as mice, voles, and ground squirrels, and the eggs and fledglings of ground-nesting birds. It competes with foxes, badgers, and martens, who eat similar things. As the number of coyotes grew, the numbers of these smaller predators declined.

Wolves frequently left remains from their kills. These leftovers were taken by scavengers such as magpies, ravens, and vultures. Without the wolf, these species began to decline.

Meanwhile, large herbivores such as the elk were safe. The population of elk in the highlands grew so large that they stripped the hills of plants. Diseases spread rapidly within their large herds, causing the population to decline.

The Return of the Wolf

The wildlife managers of Yellowstone National Park in the United States saw these signs and recognized that something was seriously wrong. In 1987 they put together a plan: they were going to import wolves from Canada.

Despite continuing resistance from local ranchers, who feared for their sheep and cattle, 35 wolves were transplanted from Alberta in 1996. More have since been added. Signs of change are already evident. Where wolves have been introduced, elk have moved from open fields (where they are more vulnerable), and now stick to tree-covered areas. Vegetation is recovering, and the number of small predators, such as the kit fox, is increasing. As ranchers feared, some of the new wolves have killed livestock. Five cows and 53 sheep were killed by wolves in Idaho in the spring of 1997. Ranchers are compensated for losses to wolves, but they are still not happy about the reintroduction of wolves.

Figure 7
In 1996, wolf packs were relocated from Alberta to Yellowstone National Park in an attempt to restore an ecological balance.

Understanding the Issue

1. Classify the at-risk status of the wolf in and around Yellowstone National Park
   (a) before European settlers arrived,
   (b) during the bison hunt,
   (c) after ranchers arrived, and
   (d) in 1996.
2. How might the views of Aboriginal people about the wolf lead them to treat wolves differently than European settlers and hunters did?
3. Make a concept map showing how the removal of the wolf caused problems in the local ecosystem.

Different Views

The following are three views on what should have been done about wolves in Yellowstone Park.

The Frontier View: To feed ourselves and the hungry of the world, we must open up, clear, and claim wilderness areas for ranching and other forms of agriculture. Wolves endanger that effort. They kill cattle and sheep. They must be removed wherever they interfere with farming and ranching, and they should not be reintroduced once they have been extirpated.

The Stewardship View: Humans are the most intelligent animals on the planet. It is our duty to take care of other species and preserve our world. Once we recognize that we have damaged an ecosystem, we must try to repair the damage using whatever resources are available to us. Wolves must be preserved in all ecosystems where they are now found, and reintroduced to ecosystems where they once lived.

The Ownership View: Canadians do not own wild animals or plants just because they live in Canada. We have no right to move them around whenever we feel like it. It may have been a mistake to kill the wolves of Yellowstone, but we have no right to take Alberta wolves and move them to a place they've never been before. It is better to let the ecosystem in the park find a new balance. Perhaps one day wolves will find their own way to the park.

Take a Position

- Should we have captured wolves in Alberta and shipped them to Yellowstone National Park? After a group discussion, decide which views you support, or develop an alternative view.
- Using libraries, the Internet, and CD-ROMs, research to find information that will support your position and write a report on the results of your research.

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SUMMARY Equilibrium Unbalanced

- The frog can serve as an indicator species whose decline signals an unhealthy environment.
- Detritus food chains are critical in the recycling of matter in ecosystems. They include decomposers, organisms that break down detritus to get nutrients for their own use, but in the process also release nutrients to the soil and water. Plants and algae use those nutrients to grow.
- In Canada, 12 species are extinct, while over 450 species are at risk. Some are extirpated (extinct in some former ranges), while others are endangered, threatened, or of special concern.

Section 1.2 Questions

1. Explain how each of the following factors could lead to the extinction of a species. With each explanation include an example of a species threatened by that factor.
   (a) poor reproductive success
   (b) competition from a species newly introduced into an ecosystem
   (c) change in climate
   (d) hunting by humans
2. Choose one of the species listed in **Figure 2**, on page 11, for further research. Why is the species at risk? Are there any initiatives underway to improve the status of the species? What could you do to help? Report on the results of your research.

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3. (a) Explain why the life cycle and skin of the frog make it a good indicator species if you want to determine the health of local ecosystems.
   (b) Construct a concept map that links the decline in the number of frogs to factors that may cause the decline.
4. (a) Design a scientific experiment that would assess the impact of acid rain on one species of frog.
   (b) If you actually carried out such an experiment, what would happen to the animals on which you experimented? From an ethical perspective, discuss your experimental design.
5. (a) Predict which area of Canada has the greatest number of organisms at risk. Provide a hypothesis that explains why wildlife in this area would have more problems.
   (b) Do national and provincial parks help alleviate this problem? Explain.
6. The peregrine falcon was once considered endangered. Research Canadian efforts to restore this predator and report on their success.

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Outcomes

Knowledge

- explain the structure of ecosystem trophic levels, using models such as food chains and webs (1.1, 1.2)

STS

- explain that the process of scientific investigation includes analyzing evidence, and providing explanations based upon scientific theories and concepts (1.2)
- explain that science and technology have both intended and unintended consequences for humans and the environment (1.2)

Skills

- analyze data and apply mathematical and conceptual models by: analyzing data on the diversity of plants, animals, and decomposers of an endangered ecosystem and predicting a future outcome (1.2)
- work as members of a team and apply the skills and conventions of science (all)

Key Terms

1.1

dynamic equilibrium
biosphere
biotic components
abiotic components
population
community
ecosystem
biodiversity
food chain
producer
consumer

1.2

indicator species
herbivore
carnivore
omnivore
detritus
decomposer
habitat
ultraviolet radiation
ozone

MAKE a summary

1. Using as many key words from the chapter as possible, construct a concept map that links key ideas within the chapter. The following Key Terms must appear in your concept map.

   abiotic components
   biotic components
   consumer
   dynamic equilibrium
   population
   community
   detritus
   ecosystem
   producer

2. Revisit your answers to the Starting Points questions at the start of the chapter. Would you answer the questions differently now? Why?

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The following components are available on the Nelson Web site. Follow the links for *Nelson Biology Alberta 20–30*.

- an interactive Self Quiz for Chapter 1
- additional Diploma Exam-style Review Questions
- Illustrated Glossary
- additional IB-related material

There is more information on the Web site wherever you see the Go icon in the chapter.

EXTENSION

CBC radio ONE QUIRKS & QUARKS

Does a Bear Shed in the Woods?
Grizzly bears in western North America have a restricted range. Dr. Micheal Procter (University of Alberta) is working on bear DNA, and has found that the southernmost bears are isolated, making them more prone to local extinction. Dr. Proctor conducted his research while studying at the University of Calgary.

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EXTENSION

Bye, Bye, Blue Bayou
This short video discusses the loss of wetlands in the Gulf Coast area of United States. The wetlands in this area are one example of how human activities, including those that contribute to climate change, can affect ecosystems and lead to extinction of species. The loss of the wetlands also has consequences to human life.

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Chapter 1 REVIEW

Many of these questions are in the style of the Diploma Exam. You will find guidance for writing Diploma Exams in Appendix A5. Science Directing Words used in Diploma Exams are in bold type. Exam study tips and test-taking suggestions are on the Nelson Web site.

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DO NOT WRITE IN THIS TEXTBOOK.

Part 1

Use the following information to answer questions 1 to 4.

Figure 1 is a diagram of an ecosystem.

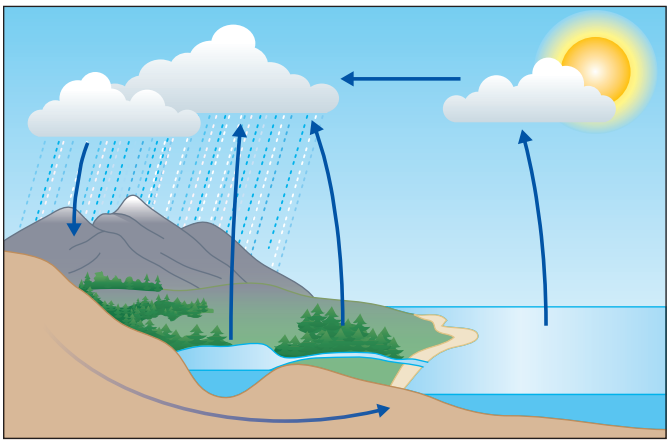

Figure 1

1. Identify three abiotic factors of the ecosystem shown in **Figure 1**.
- A. rain, sunlight, and soil quality
- B. water temperature, water lilies, and minnows
- C. poplars, grasses, and earthworms
- D. soil quality, bacteria, and earthworms

2. Explain how two members of the biotic community affect an abiotic factor.
- A. Pine trees and poplar trees affect the growth of grasses.
- B. Beavers and shrubs affect the number of poplar trees.
- C. Water temperature and pond oxygen levels affect the amount of plankton in the lake.
- D. Poplar trees and shrubs lose their leaves, which are decomposed and improve soil quality.

3. Identify the statement that lists two decomposers and correctly explains their role in the ecosystem.
- A. Clams and algae improve soil quality by returning organic nutrients to the soil.
- B. Bacteria and earthworms improve soil quality by returning organic nutrients to the soil.
- C. Pine trees and shrubs perform photosynthesis and add oxygen to the ecosystem.
- D. Algae and bacteria perform photosynthesis and add oxygen to the ecosystem.

4. What is the ultimate source of energy for the ecosystem NR shown in **Figure 1**?
- A. water
- B. sunlight
- C. producers
- D. consumers

5. Air temperatures were measured various distances above and below the soil in two different communities, a grassland community and a woodland community. Data was plotted on the graph in **Figure 2**.

Statements:
1. Woodland communities offer more shade and lower soil temperatures.
2. Woodland communities have more animals because of lower soil temperatures.
3. Temperatures increase below the soil surface, so burrowing animals must protect themselves against the heat.
4. The greatest variation between temperature readings for the two communities occurs at the soil surface.
5. Warmer air temperatures nearer the soil surface indicate that some radiant energy is reflected by the soil.
6. An animal could escape the heat by burrowing underground.

Which of these statements are supported by the data in **Figure 2**? (Record all three digits of your answer in lowest-to-highest numerical order.)

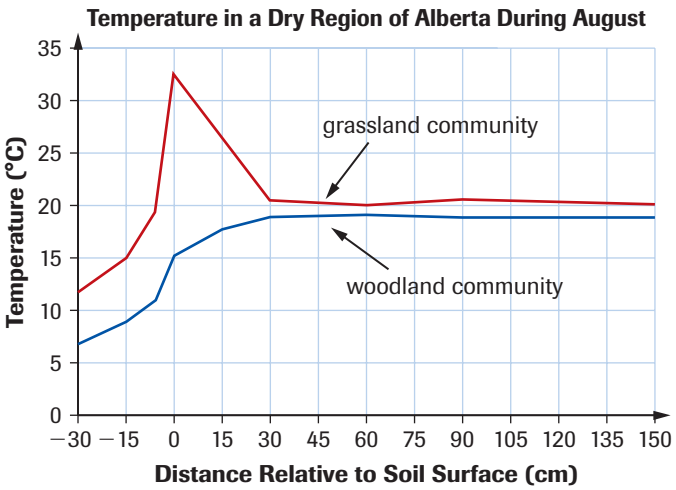

Figure 2

6. Biodiversity can be explained as
- A. the number of different species found in an ecosystem
- B. the different traits found within a species
- C. the number of organisms of the same species within a population
- D. the number of organisms of different extinct species within a population

7. Identify which choice gives two correct reasons why scientists are concerned about a reduction in the frog population.
   A. Frogs are indicator species because they are interconnected to all species in an ecosystem. Frogs are sensitive to changes in sunlight.
   B. Frogs have survived more than 400 million years. Frog populations cannot withstand the coming of an ice age.
   C. Frogs are a part of two different ecosystems (fresh water and terrestrial). Frogs belong to two different food chains.
   D. Frog populations have been slowly decreasing for the past 100 million years and now the population is increasing. Frogs are indicator species used to predict changes in the ozone layer.

8. Identify the choice in which the terms *organism, population, community, ecosystem,* and *biosphere* are all correctly defined.
   A. An organism is a distinct form of life, classified as a separate species. A population is a group of organisms of the same species, occupying a given area at a certain time. A community is the populations of all species that occupy a habitat. An ecosystem is the biotic community and its physical environment. The biosphere is the area of Earth in which life is found.
   B. An organism is the biotic community and its physical environment. A population is a group of organisms of the same species, occupying a given area at a certain time. A community is the populations of all species that occupy a habitat. An ecosystem is a distinct form of life, classified into separate species. The biosphere is the area of Earth in which life is found.
   C. An organism is the populations of all species that occupy a habitat. A population is a group of organisms of the same species, occupying a given area at a certain time. A community is a population of the same species, occupying a given area at a certain time. An ecosystem is the biotic community and its physical environment. The biosphere is the area of Earth in which life is found.
   D. An organism is a distinct form of life, classified as a separate population. A population is a group of organisms of different species, occupying a given area at a certain time. A community is the populations of all species that occupy a habitat. An ecosystem is the biotic community and its physical environment. The biosphere is the area of Earth in which life is found.

Part 2

9. Human interference often causes ecosystems to change. **Illustrate** with an example
   (a) how human interference has caused an increase in the population of a species.
   (b) how human interference has caused a decrease in the population of a species.
   (c) how the rapid increase in the population of a species has affected another species.

10. **Why** might a species be classified as endangered?

11. (a) In your own words, **describe** the classification system for at-risk species.
    (b) **Why** is a classification system like this useful?

12. **Identify** whether each of the following species is extinct, endangered, extirpated, threatened, or vulnerable. **Explain** your classification.
    (a) The wood turtle is found in pockets throughout southern Ontario, southern Quebec, New Brunswick, and Nova Scotia. The number of wood turtles in Canada seems to be stable, but in the United States their numbers are decreasing as many are being taken from the wild into homes as pets.
    (b) Furbish's lousewort is a tall herb that grows on riverbanks. In Canada, it grows only on a 200-km stretch of the Saint John River in New Brunswick. Forestry, farming, and flooding caused by hydroelectric dams all affect the area in which it lives.
    (c) The greater prairie chicken has not been seen in Ontario, Manitoba, or Alberta for many years. It was last seen in Saskatchewan in 1977. It can still be found in the prairie states of the United States.

13. (a) A decline in the number of frogs would affect other species. Using the term *food chain*, explain how the decline would affect insects and algae.
    (b) In a paragraph, **explain** the differences between the two food chains to which the frog belongs. **Describe** the role of the frog in each chain.

14. **Outline** in a list things that you could do, or avoid doing, that might help frogs to survive. Identify the things that would be easy for you, and those that would demand sacrifices. Would you be willing to do the hard things to save frogs? **Explain** your answer.

15. The common cockroach is not at risk of extinction. In fact, it is one of the species that have benefited from human activities.
    (a) **Hypothesize** about which human activities benefit the cockroach.
    (b) If a chemical company invented a spray that could kill all cockroaches, would it be acceptable to use the spray to make the cockroach extinct? **Explain** your position in a letter to the chemical company.

16. The bald eagle is not listed as at risk in Canada. Should resources be used to help restore this bird in the prairie provinces? **Justify** your answer.

17. Research the disappearance of the whooping crane from Wood Buffalo National Park along the Alberta–Saskatchewan border and **summarize** your findings in a report.

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